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17. ABSTRACT (MAX. 250 WORDS) The past, present, and future use of programed instruction in education is discussed. In 1962 more than 100 programs were available to schools, but quantity was not matched by quality. There was no concerted effort to train teachers in the expert use of programs nor any general movement of teachers colleges to use programed instruction.

Programed instruction can play an important role in meeting three challenges in contemporary education: it can meet the challenge of the individual student's aptitude and readiness because of its ability to fit its pace to the student's pace; it can ease the challenge of the traditional structure of education with its emphasis on the self-contained classroom and regular annual progression through the grades by having programs substitute at times for the teachers who are not available; and it can meet the challenge of the educational explosion in underdeveloped countries with teacher shortages.

If programed instruction is to succeed, more effort should be expended on experimentation, more research should be directed at the larger implications and theoretical problems, schools should use programs more imaginatively, teachers should be trained to use programs expertly, the skills and understandings of programed instruction should be shared with the developing nations, and adequate channels of information should be established among interested parties.

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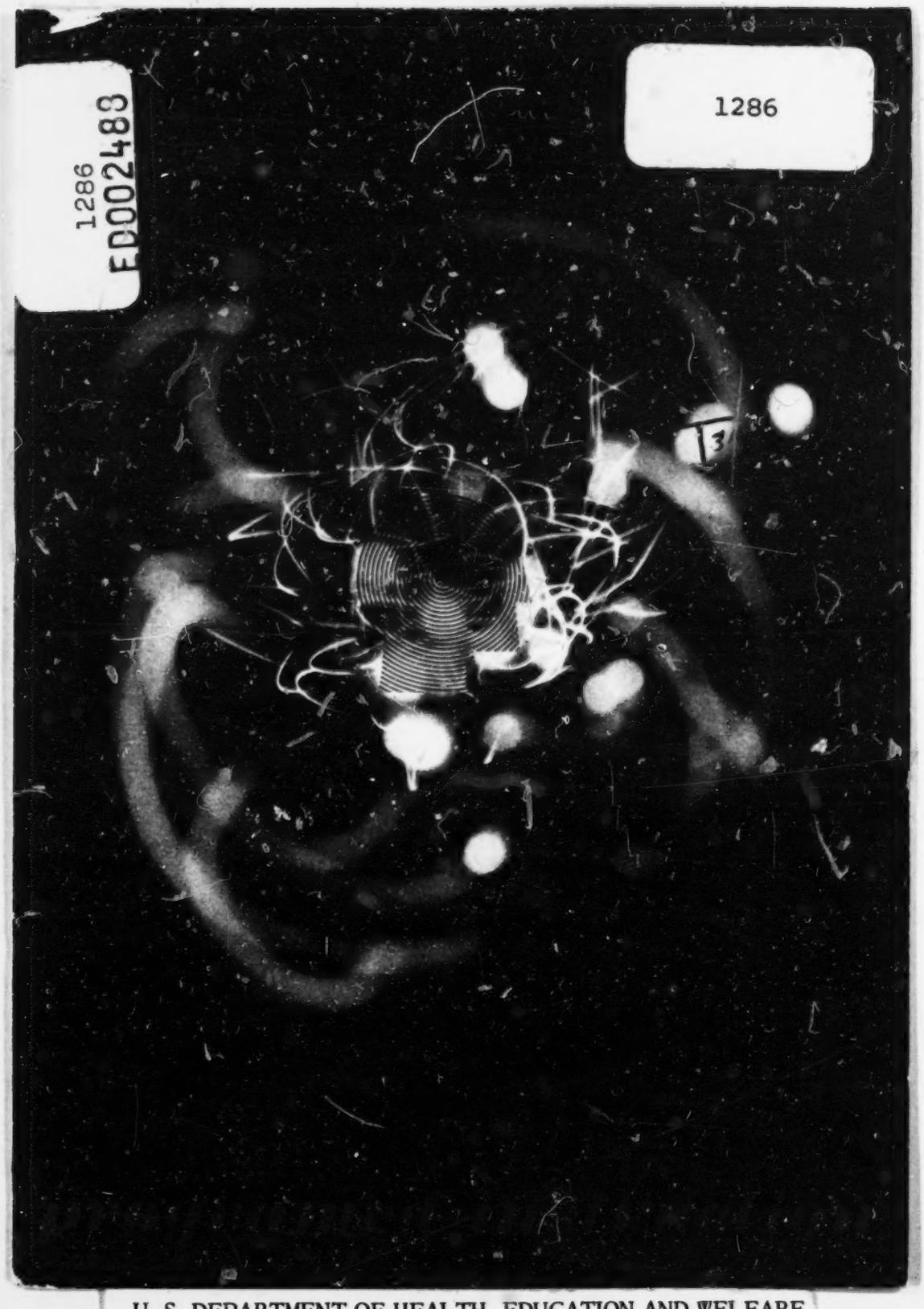

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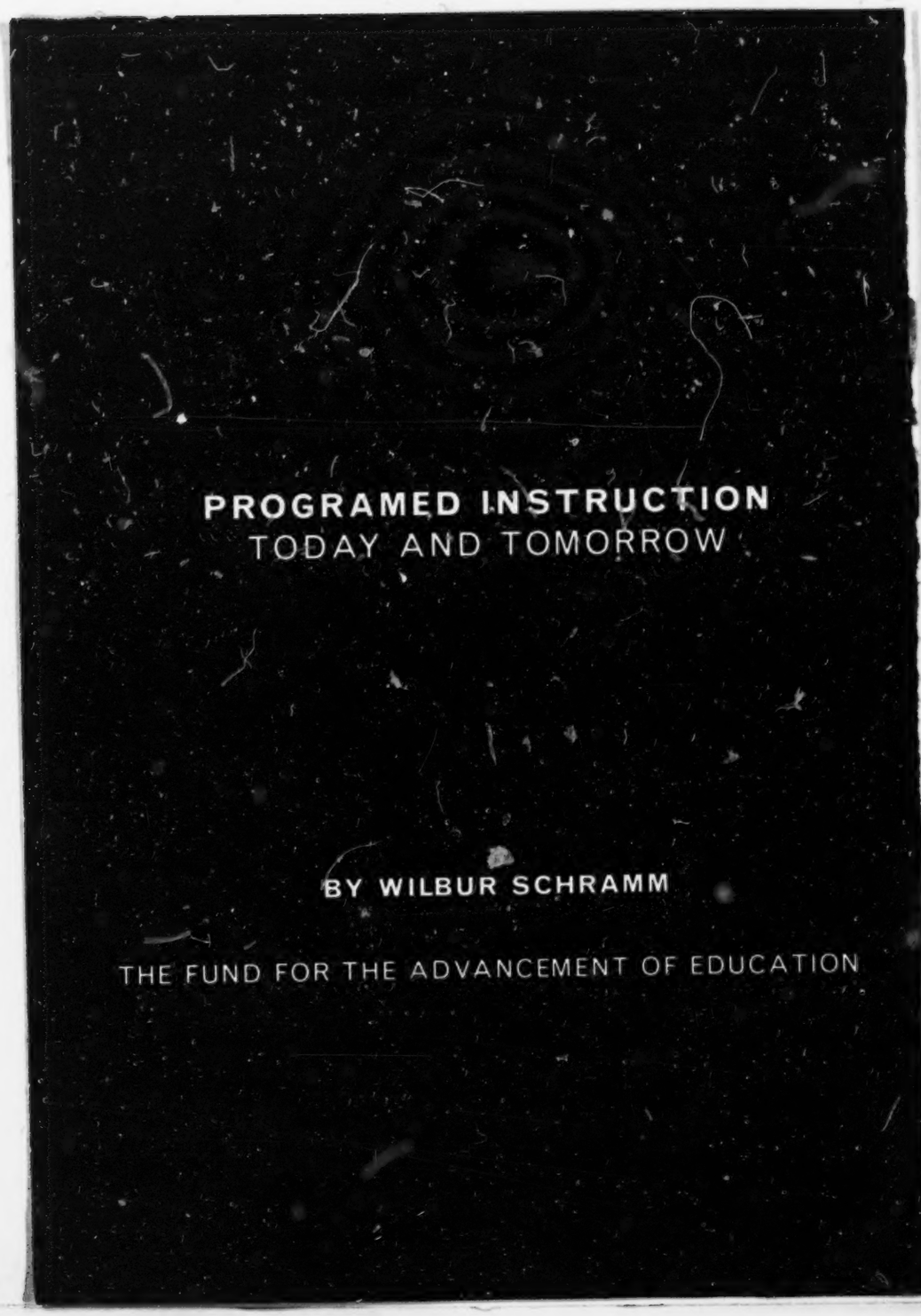
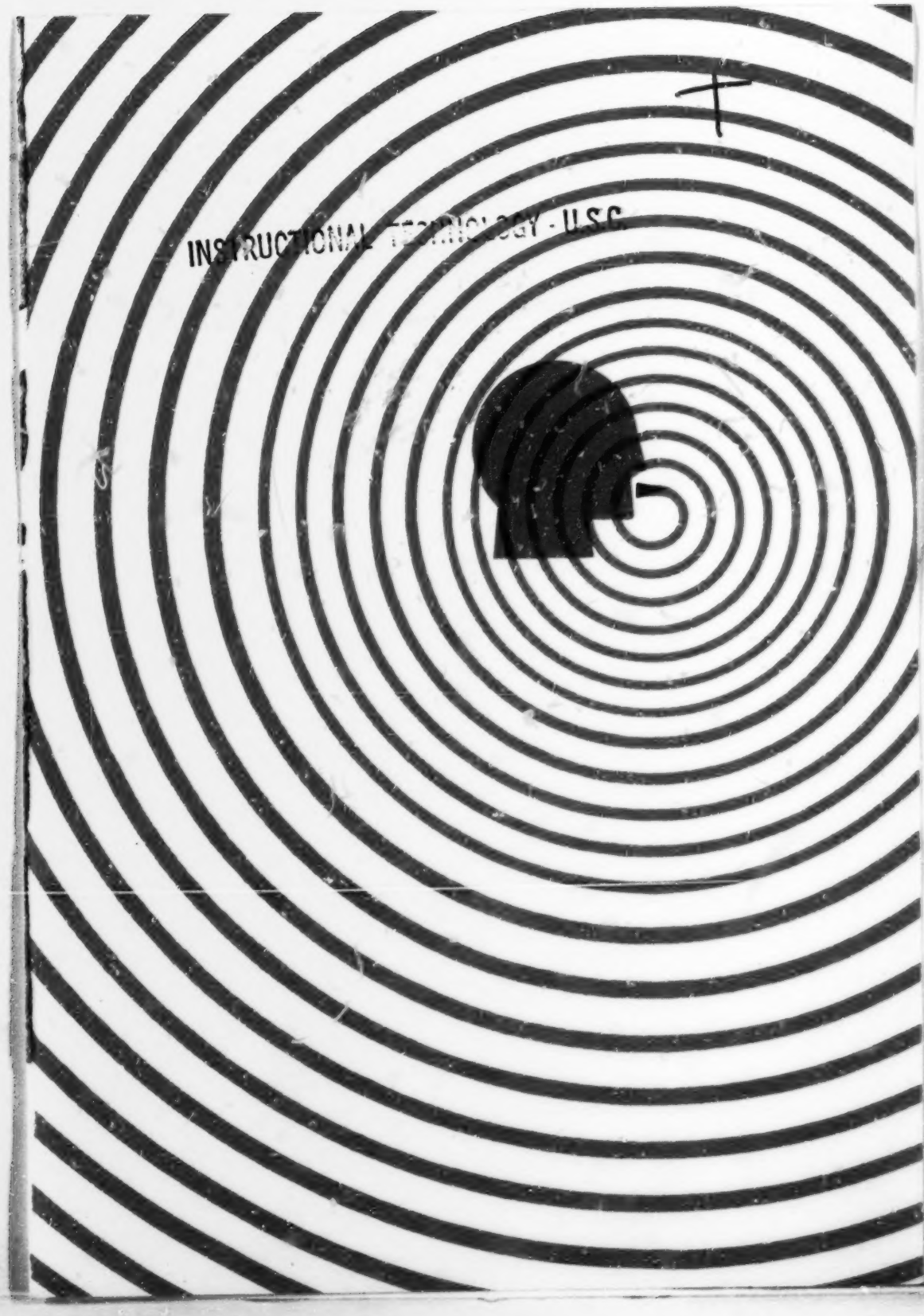

PROGRAMED INSTRUCTION
TODAY AND TOMORROW
BY WILBUR SCHRAMM
THE FUND FOR THE ADVANCEMENT OF EDUCATION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The thesis of this report is that programed instruction is, in the best sense of the word, a truly revolutionary device; but it is revolutionary, not so much in itself, as in its ability to interact with certain other developments in education. This interaction has the potential of freeing schools and men from old bondage and outworn theories and practices. But the potential is, so far, largely unrealized.

I am going to try to make clear what I mean, by talking about programed instruction as it is today, then about some of the currents in education which are boiling up around it, and finally about what it might be tomorrow, in connection with which I shall make some suggestions as to how a desirable rate and pattern of development might be encouraged.

But first let us be sure that there is no misunderstanding of what we mean when we speak of "programed instruction."

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WHAT IS PROGRAMED INSTRUCTION?

BY PROGRAMED INSTRUCTION I mean the kind of learning experience in which a "program" takes the place of a tutor for the student, and leads him through a set of specified behaviors designed and sequenced to make it more probable that he will behave in a given desired way in the future—in other words, that he will learn what the program is designed to teach him. Sometimes the program is housed in a "teaching machine" or in a "programed textbook." If so, the machine or the book is little more than a case to hold the program. The *program* is the important thing about programed instruction. It is usually a series of items, questions, or statements to each of which, in order, the student is asked to make a response. His response may be to fill in a word left blank, to answer a question, to select one of a series of multiple-choice answers, to indicate agreement or disagreement, or to solve a problem and record the answer. As soon as he has responded to the item, he is permitted to see the correct response so that he can tell immediately whether his response has been the

right one. But the items are so skillfully written and the steps are so small between them that the student practices mostly correct responses, rather than errors, and the sequence of items is skillfully arranged to take the student from responses he already knows, through new responses he is able to make because of the other responses he knows, to the final responses, the new knowledge, it is intended that he should command.

To sum up, then, these are essential elements of programed instruction:

(a) *an ordered sequence of stimulus items,*
(b) *to each of which a student responds in some specified way,*
(c) *his responses being reinforced by immediate knowledge of results,*
(d) *so that he moves by small steps,*
(e) *therefore making few errors and practicing mostly correct responses,*
(f) *from what he knows, by a process of successively closer approximation, toward what he is supposed to learn from the program.**

*We have described a Skinnerian type of program. About 19 out of 20 programs being made today are Skinnerian programs. There are other types, however. One of them is the Crowder type, represented in the Tutortexts which are in the form of scrambled books. Crowder's programs use the response as a test of whether the student has grasped an essential point of a passage of text, and provide for frequent errors by explaining why an erroneous response is wrong. There are also some training de-

However, there are two other characteristics of the making of programs which are very important in the total effect. Before a program can be designed, it is necessary to specify very clearly the desired end products—the responses the student is supposed to be able to make when he has completed the program, the skills and understandings to be learned. This requires a fresh look and often some hard thinking about the necessary content of teaching, an experience which is highly salutary and frequently results in long-overdue revision of courses and requirements. Secondly, when a program is being made it is necessary to test it. This is ordinarily done by trying it on one student, revising it to take care of the difficulties encountered in his learning experience, trying it on another student, revising it again, and so on until it has been tested on eight or ten individual students, at which time it is usually tested on larger groups. Experienced programers feel that by the time eight or ten individual tests and revisions have been completed, the program is capable of teaching 98 per cent of all the students who approximate the school and ability level of the students so far tested. This process is a very important one because (a) it focuses attention on the individual learning process

vices which are essentially programs, but not precisely of a Skinnerian type. Pressey's punchboards, employed usually as review tests, are also a type of program. All these devices, like Skinnerian programs, depend for their effect on some type of psychological conditioning, although whether it is Skinner's operant conditioning, Pavlovian or classical conditioning, or Guthrie's contiguity learning, or some combination, depends on the program and is to some extent a matter of disputed interpretation.

in a way that group teaching seldom does, and (b) it virtually guarantees that a program so made will "work." About a program so made, one feels a confidence that few textbooks can command.

It is obvious that what happens in programed instruction might well happen at a skillfully planned and organized tutorial session, in which the tutor leads the student along, question by question, toward given learning goals. A teacher is an ideal "teaching machine;" and excellent teaching, if it requires active responses by the student, employs strategy and tactics which we should call a "program." In a sense, teacher training and preparation for classroom teaching is "programing" the teacher, although much teaching—for example, lecture teaching which minimizes active response from the student—does not make use of the methods of programed instruction. But no one contends that a very skillful teacher could not do whatever a program can do, at least as well as the program can do it—except in one respect: the teacher can tutor only one student at a time.*

* The argument that programed instruction will replace the teacher is a kind of sensational and uninformed journalism which is unworthy of attention. Along with textbooks, teaching films and slides, instructional television, workbooks, chalkboards, and many other such things, programed instruction is one of an arsenal of teaching devices at the command of the teacher to help him do his job better.

PROGRAMED INSTRUCTION TODAY

IT IS NOW eight years since a short paper by Professor B. F. Skinner, read to a conference of psychologists, printed in two journals and later several times reprinted, first called the attention of large numbers of the academic community to the possibilities inherent in programed instruction. During the last five years the method has gradually been coming to public notice, moving into the discussions of professional educators and school boards, into the plans of educational publishers and film makers, and into the stage of cautious trial and limited use in the schools.

Rate of Development

Five years ago, the skill of making programs was limited to a mere handful of persons, and the first purchasable programs had not yet come on the market. Now, some hundreds of people have tried their hands at programing and have produced a very large number

of programs and partial programs, of which more than one hundred, on every level from preschool to professional school, are now available to schools who wish to buy them.* Some hundreds of schools and upwards of a million students have used programs in instruction. These numbers are due to be increased considerably in the academic year 1962-1963.

On the whole, then, the rate of development in number and extent has been all that one could expect. There has been no corresponding rate of development in quality of programs, and yet the reports from the schools are generally good. The students learn from the programs, and enthusiastic comments far overbalance the complaints about "inefficiency" of materials, or "mechanizing" of teaching. There were at least two cases where indignant individuals in school systems demanded legislation barring programed instruction from schools. Whether this was due to poor programs, poor use of programs, or teachers who felt threatened, is not now known; and the storms seem to have blown over. Aside from a few reactions such as these, the chief negative comment from schools is that many students find the programs dull, and the second most common is that because of different rates of progress among students the programs are sometimes difficult for the teacher to administer. And these, as we have indi-

*Finn and Perrin's estimate of 630 programs is apparently a blue-sky figure, including the most optimistic predictions of all program producers and the most inclusive definition of program. Querying all publishers, for the Office of Education, in the winter of 1961-62, Komoski arrived at an estimate of 122 programs that would be on sale to schools before the end of 1962.

cated, are overbalanced by reports that students like the programs, and that teachers find them helpful.

Activity in Schools and Teachers Colleges

As yet, there has been no widespread movement of school systems to train their teachers in the expert use of programs, nor any general movement of teachers colleges to make use of programed instruction. This is somewhat surprising, inasmuch as programed instruction offers new opportunities to make improvements in what happens within the classroom, and also presents the teacher with a new series of problems chiefly related to individual student activity and rates of progress. On the whole, schools have tended to absorb programs into familiar schedules and procedures, and have apparently not felt the need to conduct much inservice training. Relatively few summer workshops have been available to teachers who would like to learn more about how to make and use programs. Perhaps as a consequence, there has been little indication as yet of new and imaginative uses of programs in the classroom. For example, programs seem seldom to have been used as a member of the team in team-teaching, or in any very exciting way to achieve the old goal of individual rates of progress, or combined in a new package with other kinds of teaching so as to make one unified and uniquely powerful learning experience. There may have been such, but they have not yet become widely known. As will be suggested later in this paper, such uses should be sought out and encouraged. It is not wholly surprising that in these first years, with both the programers and the

users inexperienced, and therefore doubly anxious not to review or repeat too little, the programs should sometimes be dull and the uses sometimes unimaginative. But it is nevertheless a matter for regret.

The teachers colleges might be expected to take more leadership than they have taken in this respect, both in training present and future teachers in the art, and in experimenting with classroom uses and with new types of programs. Programed instruction would seem to be a particularly powerful tool in teacher training because it focuses attention on the processes by which children learn, rather than on the way a teacher administers a classroom. The scarcity of activity of this nature has been rather disappointing.

Hardening of Program Styles

Another disappointing development is that programing seems to have somewhat hardened, rather than loosening and mellowing with a little age. Nineteen out of 20 programs being made today are Skinnerian programs, as we have said, and Crowder's own Tutortexts represent the only substantial production of Crowder-type programs. Even within the Skinner type of program, there have been signs of hardening into a fixed and mechanical technology based on the first programs and the first writing about programs. Many of the basic devices of programing have become requirements, and are being taken for granted on largely theoretical grounds, with little or nothing in experiment or use to justify them. One of the early advocates of programed instruction

says that "if things continue the way they are now going, programing is going to become more and more of a 'word game,' a kind of didactic anagram or 'find the cue' affair. New programers must be shown the inadequacy of present techniques in getting the necessary mediating behavior out of the student. [Otherwise] programing will, I fear, 'freeze' right where it is for a long time to come."

Commercial Activity

Part of this hardening is doubtless due to the fact that many relatively inexperienced programers are trying their hands at the art: part of it, to the great commercial pressure to produce programs. In a new field of publishing, the race is to the quick. Traditional programs can be made more quickly, and sold more readily, than experimental ones. Furthermore, scholars are bribable. The lures of fat advances and substantial author's fees have diverted many talented scholars and teachers, who otherwise might have worked on the (non-lucrative but) growing edge of programing, into the making of orthodox and unimaginative (but lucrative) programs for commercial publication.

Once the potency of the new tools was appreciated, strenuous commercial activity began. At first this activity was largely in the making and peddling of machines. For a while there were many more machines than programs. Even the publishers were deluded. One respected firm sank $50,000 in an abortive attempt to create a machine. This went on for several years, during which the firm neither published nor commissioned a program. Finally, in 1959,

it gave up on the machine, and turned its attention to the production of programed books.

Programs, chiefly in the form of programed books, have been the center of commercial activity for the last three or four years. Entrepeneurs have dashed around, signing up programers. Claims have been made in advertising that should not have been made. Stocks of companies which were announced as being in the process of producing programs shot up far beyond the levels their dividends would have predicted. (This was before Black Monday on the Stock Exchange.) Harcourt, Brace's *English 2600* has sold over 150,000 copies in the schools. Grolier is reported to have sold several hundred thousand TMI programs through its door-to-door encyclopedia salesmen; the Field Company to have sold a very large number of its Cyclo-Teachers by direct mail. Therefore, there has been good reason for commercial excitement. And although the publishers are now groaning over the cost of making programs and trying them out, the difficulties of handling programers and working with an unfamiliar kind of material, still there seems little doubt that programing will make considerable money for someone.

Regretfully, in a private enterprise country, one must admit that commercial activity in this field, so far, has been largely counterproductive to better programs and more imaginative uses. The publishers and film makers began to exploit programed learning before it was really quite ready. Faced with the need to risk large financial stakes in an unfamiliar situation, they made little attempt to find new kinds of programs or new uses of programs—rather they sought the more conservative types of programs and the more familiar uses. Faced with field reports

on their programs, they tried to avoid expensive revisions. The incarnation of programs in programed books tended to harden the form at the moment when it should have been most flexible and most responsive to test findings and new technical developments. And it must also be recorded that the commercial agencies have supported almost no research on programing. Such research as has been done has come mostly from the universities, and been financed largely by the Foundations and the National Defense Act.

Research

There has been a considerable amount of research on programed instruction—probably somewhere near 100 experiments.* Indeed, no teaching medium has ever come into use in such an atmosphere of research—born, as it was, in a learning laboratory, nurtured on theory, and for some years knowing no friends except scholars.

This research leaves us in no doubt that programs do teach. A great deal of learning seems to take place, regardless of the kind of program or the kind of students. Even a bad program is a

*It is necessary to give an approximate figure here because in a new field like this much of the research appears in mimeographed, or even typewritten, form, rather than in the journals. It is very hard to tell, therefore, whether one has seen *all* the research. Later in this report, in "A Note on the Research about Programed Instruction," I have reviewed and abstracted all the research I have been able to find on the topic.

1960-62

pretty good teacher. Programs have been used successfully at all levels of the educational system, at all levels of ability from slow learners to the very best students, and to teach a great variety of academic subject matter and verbal and manual skills.

We can accept confidently, therefore, the conclusion that programs do teach. But how they teach, and what combinations of characteristics make them teach better, is still much in doubt. Some of the research results are puzzling and, to a good Skinnerian, sometimes astounding. There is very little evidence to prove that the constructed response, which is an important part of Skinner's theory, is in most cases any better than a selected response, or a subvocal response, or no measurable response at all. Several experiments have accomplished as much learning by filling in the blanks and letting students read the items like a textbook, and others by leaving the blanks but omitting the confirmation, as by the usual process of stimulus, response, and confirmation. "Maybe we ought to be publishing textbooks," said the head of one programing organization when he saw the results of such an experiment on one of his programs. It has been shown in a series of experiments that, for paired-associate learning, the system of prompting (showing the student the stimulus and response terms together) usually makes for just as much learning as, and takes less time than, the Skinnerian process of confirmation. A few experiments have even tried scrambling the order of a short program, and the most common result is no significant difference between the learning from the scrambled and the ordered programs.

I have reviewed this research later and will not belabor the point here. But let me hasten to say that some of these results

may be due to the way the research was done. Many of the experiments, for example, used very short programs and very small samples, and it is hard to generalize from these to real-life classroom conditions. It is unfortunate that not many of the most distinguished researchers have been attracted into doing experiments on programed instruction, and that most of the research so far financed has been of a short-term nature. But there are too many results at variance with the results predictable from theory to justify us in brushing them aside. I have just finished reading the report of six experiments at a West Coast university. The professors are plainly puzzled by their results. In the early experiments, they got so many results contrary to theory that they doubted their own measurements and worked hard to perfect their tests. Having so done, they still got much the same kind of result. They concluded that they had no evidence to believe that the standard Skinnerian program, used throughout their experiments, produced significantly better learning than any of several other forms, and that "the necessity of providing practice and reinforcement at each step of the program must be seriously questioned." It is clear, then, that programers are taking for granted a number of devices and rules of programing which are far from being adequately understood or confirmed by the evidence.

Although these uncertainties in research findings are disturbing, in another sense they are encouraging. There is every reason to hope that the use and study of programs, and the resultant focusing of attention on the processes of human learning, may feed back into the laboratory sufficient new information to make possible a major advance in learning theory. As Ernest

Hilgard has said, the typical theory of learning may have little relation to what goes on in a human being when he learns. The need to study programed instruction should help to bring theory and actuality closer together. And if research on programs can illuminate learning theory, then we can be confident that improved theory will illuminate and improve programing.

In another way, also, the research is encouraging. It gives us every reason to believe that programs in the future *can* be vastly different and more effective. The experiments tell us, not only that we have much to learn about how to use and combine programing techniques, but also that programs will do some jobs we had not previously been sure they could handle. For example, Gagne and Brown demonstrated that programs could teach by "discovery," as well as by the usual kind of conditioning. There has been some evidence that programs can help to teach things like critical and sensitive reading of literature. Experimenters have shown that branching can be built efficiently into a Skinnerian program, so that remedial loops can be furnished for those who need them, and students who do not need additional practice or shorter steps can hurry along with giant steps. Experiments show, also, that programing can be adapted to a great variety of needs and audiences. Omar Moore uses a program to teach two- and three-year-olds to read and type. Certain programs taught a group of slow learners (mean IQ, 77) more than they had learned in any previous year of class teaching. Some remarkable things have been accomplished by using programs to telescope learning time. For example, a class of Naval Reservists, needing a cram course in Russian, used a program for the purpose, and as each one finished the program he studied part of a grammar text and

listened to tapes of a foreign language speaker. They studied for ten days, seven hours a day. Their instructor estimated that in the ten days they learned about as much as they would have learned from a semester and one-half of a beginning college course in Russian.

It is obvious that the growing edge of programing is available if we can persuade some talented programers and scholars to work on it, rather than on the more routine commercial jobs.

Overview

Looking back over the first public years of programed instruction, then, we can record a swift growth rate in production and use, some encouraging evidence that programs teach, some research results puzzling as to *how* programs teach but encouraging as to how they may be made to teach *better,* and a premature hardening in program form and use.

Ironically, it might have been better for programed instruction if, at times during the beginning years, it could have been delivered from its friends. Its friends were sometimes too friendly, too full of enthusiasm to be critical, too absorbed in their own work to take a broad look at what was happening to programs, too close to developments to be good guides either for educators or for the public. There is a maxim of flying that a pilot needs altitude in order to make a good landing. In the first years of a dynamic new development it is hard to gain altitude over it.

If we must assess credit, it is the friends, rather than the enemies (if any) of programed instruction who must be credited with an

emphasis on teaching machines rather than teaching programs, with extravagant claims of accomplishment and potential, with contributing their own rigidities to the somewhat rigid trends in the development, and with an emphasis on newness without defining the truly revolutionary quality of the newness.

The emphasis on machines derived from preoccupation with a machine that provided for review of missed items, and also from the experience of the military establishment with mechanical and electronic "trainers." It fed on the eagerness of industry to produce machines for the lucative school market. The fact that to make programs was much more difficult than to make machines, and that most of these programs, once made, could be studied at least as effectively without machines, took several years to soak in. By that time, most of the lay public and many school boards and school administrators had filed programed instruction with water-coolers and air-conditioning, rather than with curricula and teaching method. There is no doubt that in the future some types of programed instruction will be conducted with the aid of machines; programs for pre-literates and language programs requiring both sound and sight are obvious examples, and the very bulk of paper in printed programs may force publishers to put their programs on film for use in a projector-type machine. But the premature emphasis on the teaching *machine* has served to distract attention from the teaching *program,* and from the really crucial questions about how students learn and how the activities in a school are to be selected and arranged in sequence and combined.

The extravagant claims for the new method are understandable and forgivable. The truth is, it is a very effective device for

learning. The behavioral scientist was understandably proud that his science could make a major contribution, the effectiveness of which could be seen almost as readily as the great contributions of natural science. The entrepeneurs were understandably excited, and the highly competitive textbook industry was moved both to produce better products and to be first in a profitable field. It was not surprising that a group of advocates should develop. These advocates did both good and harm. They made the method known, but tended to hurry the rate of introduction beyond the rate of capability. Programs were introduced that were inadequately tested, and too hurriedly made. Teachers were made to feel threatened, rather than supported. Some schools were left feeling cheated because the programs were not miraculous. One wrote me, the other day, complaining that a certain program did "no better than a first-rate teacher." And in the research and teaching community, many able individuals who should have been studying how to make *better* programs than any now existing instead were tempted by "advances" to write programs by present-day standards, hurriedly to meet a deadline, rather than undertaking a further range.

Perhaps the less said about rigidities, the better. To some of the important figures in the early history of programed instruction there seemed to be one "right" way, and many "wrong" ways to program; one "right" theoretical position, and many "wrong" ones. This tended to close many doors to experimentation in programing, and led to many firm and authoritative statements about programed instruction, and inflexible policies in programing, at a time when the movement needed something else. We have no wish to point a finger at any individual, espe-

cially at any of those individuals who contributed greatly to the development of programed instruction. This is merely a note on another source of what we have called the premature hardening of the form and use of programing.

The emphasis on "newness" is likewise easily understandable, and a good case may be made for it. But the very exaggeration of the language that has become common—for example, "the first prose ever constructed especially for the purposes of education," "the first really new tool of education since the printed book," and the like—have served again to distract attention from where it should be directed.

Students for thousands of years have followed instructional programs. Socrates had a program intended to teach his students right thinking and virtuous living. Music students have long worked toward professional competence by a program of finger exercises or vocal exercises. Most of us used a program of flash cards to learn multiplication tables or chemical formulas or foreign language vocabulary. In fact, most of us have learned to speak by means of a more or less formal program on the part of our parents, who prompted and reinforced certain desired responses. And for an impressively organized program of learning experiences, observe what a football coach does to a squad of awkward boys five afternoons a week!

The roots of programed instruction are deep both in the theory of education and in psychological learning theory. Five hundred years ago, Comenius tried to specify a kind of education that would be active—that would cause a student to "learn more, and the teacher to teach less." Pavlov, Thorndike, Hull, Guthrie, and many others all demonstrated, before Skinner, how a labora-

tory animal or a human could be conditioned to make a given response to a given stimulus, and how a secondary reinforcer could be substituted for a primary one. The fact that Pavlovian or classical conditioning involves different manipulation from Skinner's operant conditioning, or that Guthrie's contiguity learning represents a somewhat different theory from Hull's drive-reduction or Thorndike's and Skinner's reinforcement theories, is a less important distinction than might be expected, in view of how "Skinnerian" programs are actually written, and what present-day research finds concerning the effectiveness of different forms of response and reinforcement in a verbal program.

Even Skinner's techniques of programed instruction were not wholly new. Pressey, in the 1920's, demonstrated by means of his punchboard the effectiveness of giving a student immediate knowledge of results. Several military training devices constructed in the 1940's and 1950's demonstrated the learning value of overt responses to a series of logically ordered stimuli, followed by knowledge of results. Student workbooks for years have been made on the assumption that constructed responses have a special value in learning. Skinner's contribution to this series of developments was to demonstrate a very simple, highly usable verbal learning device which is grounded in operant conditioning theory and has the ability to make maximum use of some very weak elementary reinforcers.

I am not trying to minimize Skinner's contribution. The trouble with the emphasis on "newness" was that it directed attention to the device rather than to the larger implications of the development. Skinner's teaching machine was obsolete before

other users could get copies of it. The Skinner-Holland programs, even the best of present "Skinnerian" programs, are probably only weak foreshadowing of programs that can be made in the future. Research already raises certain doubts as to why people learn from Skinnerian programs. The device is clearly not the important thing. By concentrating on its newness, we distract attention from the truly new and important qualities of the development.

It is possible that, a decade from now, Skinner's contribution may be said to be that he built a bridge from the heartland of modern behavioral science (the growing knowledge of how human behavior is controlled and shaped) to the heartland of education (the growing technology for stimulating human learning). This bridge makes it easier for educators and behavioral scientists to go back and forth between their respective kingdoms, and the results of this are potentially much greater and more beneficial than anything which has yet come out of programed instruction. Just as the classical concepts of absolute time and space in Newtonian physics hindered for a long time the development of relativity theory, so did the classical concepts of absolute thresholds, absolute ability and intelligence, absolute readiness, and so forth, for a long time hinder the development of a true science of behavior, and in particular the application of such a science to education. It is therefore of the greatest importance that just at this moment when the elements of a behavioral science are on hand, the bridge should be open between the laboratory of the scientist and the laboratory of the school. Both the scientist and the educator stand to learn something of importance, and both theory and practice stand to gain.

It is of more than coincidental interest that the door of the schools should open for the behavioral scientist just at the time when the natural scientist and the mathematician have found the way back to the schoolhouse. For as we have tried to say, the development of programed instruction is of special importance in relation to the currents in education surrounding it, some of the most vigorous of which are set up by the renewed and active interest of physicists, chemists, biologists, and mathematicians, in what happens in the schools. We must now be more specific about these currents, and how programed instruction relates to them.

THE STAGE SETTING FOR PROGRAMED INSTRUCTION

The Challenge of Curriculum

WHEREVER ONE LOOKS, in education today, he sees long-held and well-established belief and practice being challenged. Perhaps the most striking of these challenges is to curriculum. And amidst all the demands for change—demands that "life adjustment" or "progressive education" be abandoned, that the schools revise their offerings to support the national goals, that they return to something like the three R's, or phonics, or even the McGuffey readers and so forth—amidst all these, one of the most cogent and certainly the best implemented of the challenges comes from the scientists, who ask nothing less than that education change its basic purpose.

The return of the scientists, after a long period of disinterest, to an active concern with public school curricula, is itself a dramatic event. It is even more significant because these scholars are not content merely to criticize; they have insisted on dipping into school curricula, and preparing new materials. It is not surprising, these days, to find a distinguished professor of mathematics,

ordinarily seen in university graduate classes, teaching a primary grade class because he wants to prove that set theory or geometric proofs can be taught at that level. The mathematicians and physicists got there first, but the chemists and biologists are not far behind. New mathematics materials have been prepared for most of the grades, a new physics course is available for high schools, and other materials are rapidly becoming available—made, for the most part, and often demonstrated, by university scholars who are motivated by a deep sense that science has been inadequately taught in the schools, and must be taught better.

Even a casual look at the new materials reveals how different these scientists feel science teaching should be. Gone is all the emphasis on the application of science and mathematics. Scientists are no longer much interested in having students taught how an electric power station works, or how to figure compound interest on a loan or to balance a budget. "Practical" science and "social" arithmetic are very far from the thinking of these scientists-turned-curriculum-makers. They care very little about how "useful" in everyday life a course is, and they really don't want a student to master the *content* of a subject. Any content he learns today, they say, will be obsolete tomorrow. Science regenerates itself every decade. The only kind of science that will be useful tomorrow is scientific *thinking*.

Therefore, what the scientists want to do with public school students is to teach them the thought patterns of mathematicians and scientists. They are not to be taught laws and theorems and relationships; they are to be taught how to *generate* and *discover* laws, theorems, and meaningful relationships. There is a neat distinction, in the vocabulary of these scientists, between what is

meaningful and what is *useful*. Specific laws or formulas are useful in a transient way; but the ability to think in a highly generalized way, to perceive the interconnectedness of ideas, to be able to generate new laws and relate new observations to each other, is *meaningful*. In other words, what is important in science teaching is not the products of the science, but rather its *tools*.

So, in science classes, students are to be given practice in thinking like scientists. Even in their unpracticed ways, working with simple materials, they are to be encouraged to discover relationships and patterns, to develop theorems which Euclid may or may not have discovered before them, to discover over again the laws of probability and the principles of reflection and refraction. The key word is *discovery*. Students are not to be *taught* these laws and relationships; they are to be allowed to *discover* them. And by this method the scientists hope to substitute some of the joy of discovery for the deadliness of didactic teaching and memorizing. So taught, some of the best of the students will enter college better prepared to become scientists, and most of the students will be able, not only to understand some of the science around them, but also to look at their own problems in a more nearly scientific way.

This is an exciting, a challenging approach to curriculum. And if we ask what is the place of programed instruction in this new kind of curriculum, then we must ask first what are the limits of teaching by discovery? How many skills, what store of knowledge, must still be taught by practice and memorizing? The scientists tend to be rather vague about this, but clearly there are many basic tools, such as reading, spelling, grammar, multiplication tables, to which discovery can make only a limited

contribution. And how gifted must a teacher be if he is to teach effectively by discovery? Can anyone do it? Can it be done with a large group? A reasonable supposition is that not everyone can do it, and it does not lend itself to large-group teaching.

The basic ideas behind Skinnerian programing are quite different from discovery teaching. Like Thorndike, Skinner seems to be skeptical of transfer, and thinks of knowledge as consisting mostly of specifiable correct responses to specifiable stimuli. But is this the limit of programing? One of the most interesting articles in the research literature on programed instruction is the one by Gagne and Brown which demonstrates that a program can be constructed to teach by discovery. This is a finding of very great importance, for it points to the possibility of multiplying the efforts of the gifted teachers, and extending their influence beyond their physical presence and their available hours. It also points to a way of guiding discovery, to eliminate the wasteful randomness of much of it. However, it must also be pointed out that programs are not typically being made to teach by discovery, and if this is to become a major programing task then there must be an effort to develop this method of programing.

Even without discovery-programing, however, it seems likely that programs that teach by conditioning will still have plenty to do. In fact, the only way that teaching by discovery may be made practicable may be by turning the skills teaching, the routine work, the memorizing, over to programs, thus freeing the teacher for the demanding work of guiding the process of discovery. Thus, it is not at all unlikely that instructional programs and the new science curricula may prove to be able to do what neither could do alone, and together accomplish the revolu-

tionary task of freeing students from outworn patterns of learning about science.

The Challenge to Concepts of Aptitude and Readiness

Educational psychologists and teacher trainers have been pretty stuffy about aptitudes and readiness. They have pointed out that at some point the child is ready to learn to read, at some other point to learn long division, at still some other point to begin geometry or Latin. They have even been willing to specify the age at which the average (or normal, or typical) child is ready for these experiences, and in general our curriculum has mirrored these "rules."

Furthermore, there has been a deadly inflexibility about student ability. Grade average was predicted in terms of IQ; if the student did worse than that, he was said to be working below his ability; if he did better than predicted, he was said to be an "achiever." So long as all students were taught exactly the same way, the IQs and aptitude tests stood up pretty well.

But suppose that readiness depends upon teaching method as well as upon subject matter? Suppose, for example, that a student is ready for the usual way of teaching geometry only in the tenth grade, but is ready for another way of teaching it as early as the second grade? Suppose that, as in the Soviet Union, intelligence tests were to be minimized; and when a child could not understand an explanation or a concept, the blame were to be laid, not on the child's supposed lack of intelligence, but at least partly on the way the material is being taught? Suppose that testmakers

were, as Cronbach and Glaser suggested they should, to think of their assignment not as selecting the fit from the unfit, but rather as selecting the kind of instructional methods which will fit different kinds of individuals?

This is the kind of revolutionary talk that has been heard in education for the last half dozen years, and has shaken the structure of aptitude and readiness beliefs from top to bottom. Most embarrassing of all, some of the teachers who have little respect for the readiness beliefs have gotten into the classroom, and have demonstrated pretty effectively that many of these beliefs are myth and folklore. Suppes and Page, for example, have been able to teach highly sophisticated mathematical notions in the first few grades, and Keislar has been able in the same grades to explain the phenomenon of dew in terms of molecular attraction. The students both enjoy and profit from this kind of teaching. Taking note of the fact that some children learn to read before they come to school, materials have been prepared to systematize and extend this early learning experience, and they are now being widely tested. The general conclusion, after this activity, is one that would have been laughed aside little more than a decade ago. Bruner stated it when he wrote, "Any subject can be taught effectively in some intellectually honest form to any child at any stage of development."

Programed instruction becomes important in this little revolution because of its ability to fit its pace to the pace of a student, and because a program is necessarily made in such a way as to insure that it will teach a child of a given level. Using programed methods, Moore was able to accomplish his remarkable success in teaching two- and three-year-olds to read and type. Using

programed methods, Stolurow was able to get truly surprising performance out of very slow learners. Using programed methods, bright high school students in a number of places were able to study advanced mathematics, Russian language, and other subjects ordinarily studied in college—quite on their own, and outside class.

Thus programed instruction is a tool which should make it easier to break out of the traditional pattern of subject by age. As instructional television made it possible to teach foreign language in the elementary school although few elementary teachers were equipped to teach it, so programed instruction will increase the number of classrooms where subjects can be taught at an earlier age than they were formerly taught. Because the student is at the throttle, we shall find many more slow students learning a subject, and fewer bright students bored, than we found when the whole class moved at the same pace. Most important: the approach to program making is exactly the approach that is necessary in order to fit sophisticated subjects to young students. When you make a program, you work with a given set of required outcomes and a given group of children. You can't ordinarily blame a failure on the student's lack of ability or readiness; you can only blame it on a failure of the program—and you set about finding a form of program that will teach.

We don't know how far programed instruction can go in stretching limits within which a given subject is teachable, or speeding up the learning process beyond what has usually been taken as "average" progress. This will be a very exciting thing to work on, in the next ten years. To give an example, suppose programed methods were now combined with other suitable

tools in an all-out effort to speed the rate and increase the efficiency of learning to read. How much could the process be improved? The Russians claim that their students are farther ahead in reading at the end of their first year of school than our students are at the end of *two* years. If this is true, even allowing for the phonetic quality of their language, still there must be a difference in the efficiency of the teaching processes. If we could hurry up our teaching of reading one year or even half a year, in the first four years, if we could increase the efficiency of our teaching of reading only 25 per cent, scores of other educational problems would solve themselves. Given better readers, we should have better students in every other academic subject, and incidentally, better students of programed instruction.

The Challenge to the Traditional Structure of Education

For many decades the self-contained and self-sufficient classroom was almost a tenet of faith for American education. The personal and unbroken relationship of a teacher to 30 to 35 students was considered necessary both for their sense of security and their efficient academic progress. Gradually a few inroads were made on that citadel. It was found that, if the teacher in charge were not herself musically trained or gifted, a visiting music teacher could enter the fortress without doing special harm. Physical education classes, if schools had them, tended to be moved outside the classroom and taught by a special teacher. Then, in the 1950s, the roof began to fall in on the self-contained classroom. Partly it was because special demands were made on teachers—

for example, to teach foreign language or unfamiliar kinds of mathematics. Partly it was because teaching by television was tried and found to work, so that the best teachers could be shared more widely. Partly it was because the idea of team teaching began to make sense to educational administrators. Team teaching challenged the idea that 30 to 35 children was necessarily the right size for a class; some classes could be taught well with 100 students in the classroom, and others could not be taught well to more than five or six. It challenged also the idea that one teacher per year per class was necessarily the best use of teaching resources. The advocates of team teaching said that some teachers were more effective at one kind of teaching, some at other kinds; furthermore, some of the chores of a classroom teacher could be handled by clerks or graders, and the teacher freed to do what she was supposedly uniquely trained to do—teach.

While the roof was falling on the self-contained classroom, the foundation was crumbling beneath the related belief in a regular measured annual progress through the school grades. For a long time, school men had been uneasy with this arrangement. They were aware of individual differences in ability and motivation, and tried various ways of making allowance for these differences. The idea of substituting unit texts and individual assignments for inclusive textbooks and common assignments was tried and worked well in some places, although it was always hard in a class of 30 to 35 to administer individual activities and rates of study. The multiple-track idea, in which classes were segregated by level of ability, the most able classes getting an "enriched" course, and the least able ones a reduced or remedial course proved easier to administer. In the 1950's, however, more radical solutions

have been tried. One of these is the ungraded school. Another is the dual progress plan, proposed by scholars at N.Y.U. and tried in some nearby high schools. In this plan, the home room teacher takes the class for half a day, concentrating on tool subjects—e.g., grammar—and maintaining a fairly regular rate of progress per grade. During the other half of the day, under another teacher or teachers, the students are free to go at their own pace and follow out their interests and discoveries in subjects which lend themselves especially well to that kind of study—e.g., science. Thus a student might conceivably be studying Boolean algebra or the structure of the atomic nucleus, at the same time as he was studying sentence structure at the third-grade level. He might have some of his work with fifth, and some with eighth graders. As a matter of fact, he might be the only student in the school studying Boolean algebra. This is how far the growing edge of experiment in education has moved from the self-contained classroom.

It is easy to see how programed instruction fits into this development. Either the ungraded school or the dual progress plan presents a perfectly horrendous problem in scheduling and taking care of all the individual needs and assignments. *Any* structure that provides for individual assignments and individual rates of progress does present a severe administrative problem. The only ideal way to solve it is to have one teacher per subject per level. And the nearest approximation we can make to that ideal arrangement is to let programed instruction, where possible and appropriate, sit in for some of the teachers we don't have.

We probably have no teacher we can turn loose for ten hours of tutorial work to guide that bright third grader through the Boolean algebra which has excited and challenged him. But a

program can do it. When the student gets to a point in his individual progress where he needs to know how to extract square root, and hasn't been taught it, are we going to ask a teacher to tutor him—or let him work through a self-instructional program on square root? I am not suggesting that students working at their own rates will do all their work in programed instruction. Far from it. They ought to read voraciously, and write, and explore, and discuss, and experiment. But they will find many topics where they need more help than a book will give them. They will find many areas in which they need to be guided toward discovery, rather than moving randomly around looking for something new. In some of these situations a teacher can guide them. But in many others a teacher will not be available, and here a good program ought to be most welcome and effective.

In fact it may be only through the wise use of programed instruction that the administrative difficulties of the ungraded school and the dual progress plan can be overcome with sufficient ease as to make the plans widely feasible. It would seem that a selection of excellent programs would be equivalent to adding expert and specialist teachers to the team. In particular, schools which are not ready to go to one of these advanced patterns, can add excellent visiting teachers in the form of programed instruction, without any risk to the relationships in the one-teacher classroom.

In short, the advent of programed instruction, just at this time, may administer the coup de grace to the old dragon of of progress-by-yearly-lockstep in the closed classroom.

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The Challenge of the Educational Explosion

In this country we have what we call an "education explosion," meaning a great increase in the number of school-age children. Our education explosion is a mere toy pistol compared to what is going on in Africa, Asia, the Arab States, and Latin America. Sixty states in those areas are grasping for nationhood, trying to accomplish in a hurry the social and economic growth which older nations took centuries to accomplish. We recognize the education problem as important; these new nations recognize it as crucial. Before they proceed far along the road of development, well over half a billion people must be taught to read and write, and introduced to the simple computational skills. Hundreds of millions of people must be taught new practices in agriculture, health, and home management. Almost as many must be upgraded in occupational and mechanical skills. New industries, new public works, new service occupations must be manned, and new machinery must be operated. This whole complex of needs calls for a literacy teaching program, an expansion of school systems and technical training, an increase of inservice training and community development instruction. The total need is so vast as to be almost beyond comprehension.

Could an intelligent use of programed instruction significantly reduce the time and money required for that task? Everyone who is familiar with programed instruction and has looked closely at the needs of the new states is most optimistic about what could be accomplished. These countries are desperately short of teachers; here is a device to multiply good teachers. These countries have unusual motivations to learn; here is a device to take advantage

of these motivations and provide a tool for self-teaching. These countries have need for a considerable amount of expert and specialized teaching which is often not within the competence of many of their teachers. Countless one-room schools are in charge of teachers who themselves have only four to six years of education. How much the learning opportunity in those one-room schools could be increased by the addition of a small library of well-made programs! This is the kind of possibility that leads observers to say that the greatest contribution of programed instruction to education may well be made in the developing countries.

Yet the introduction of programed instruction to developing countries presents some delicate problems, and must be accomplished with caution and insight. The problem is one of sharing skills, findings, and materials in a sensitive and culturally bound area. The United States, where most of the work on programed instruction has been done, must be prepared to share with the new states, and certainly will do so. *How* it does so is of the greatest importance. The new states must be encouraged to resist fast-talking salesmen who try to sell them programs and machines made in and for the United States. At the very least, these programs must be translated culturally as well as linguistically, and purchase of the machines may well be an unnecessary expenditure. Furthermore, a nation's education is a precious national possession and responsibility. The way to introduce a revolutionary new method like programed instruction into a national system is not to introduce materials but to introduce the method—to build up competence in the new country so that *it* can decide what programs it wants made, what use it wants made of the tools, what

it wants to buy, and what teachers it wants trained in the new techniques. We are not certain how many American programs would be usable in any of these new cultures; we are not even certain what changes would be required in the programing method itself. Therefore, any introduction of programed instruction into a developing culture should be done in the spirit of trial. Research should be combined with development, and the findings should be shared as widely as possible, not only within the country but among the developing countries. Up to this point, we should be concerned with sharing our knowledge with the new states. Only after we understand the requirements of programing for the given culture, and only after the country has built up competence to make its own decisions about programed instruction, should we think of what materials of programed instruction we can *sell* the country.

But if we can introduce the method in this enlightened way, then the potential of programed instruction in national development is a most exciting and promising one.

We have already suggested other challenges to programed instruction—the challenge to contribute to a more adequate theory of learning; the challenge to make more efficient use of the learning capabilities of all children; the challenge to make better use of the learning capabilities of children at far ends of the capability spectrum, both the slow and the very swift learners; and the challenge to extend education efficiently beyond the school to correspondence students, self-teaching students, and students who need home work and practice to go with television instruction.

These are the things that are in our minds when we speak of

the truly revolutionary qualities of programed instruction. The method is not revolutionary per se; it challenges schools *to be* revolutionary. Potent in itself, it will be doubly potent if it can be applied to problems like those we have mentioned in this section. The true revolutionary quality of programed instruction lies in its potential for helping to free man from inadequate curricula, from inflexible concepts of "readiness" and abilities, from the poverty of the self-contained classroom and the lockstep of annual progress, from generations of ignorance in traditional societies, from inadequate theories of learning and inadequate use of capacities to learn.

SUMMING UP—THE STATE OF PROGRAMED INSTRUCTION

LOOKING BACK over the last pages to the thesis with which this report began, it is difficult to conclude that more than a tiny fraction of the potential of programed instruction is being realized. I should sum up the present state of programed instruction in these three propositions:

(1) *Although the research gives us little reason to be satisfied with the theories and the standards of today's programing, and every reason to believe that it will be possible some day to make programs vastly more effective than today's programs, nevertheless programed instruction shows signs of hardening, partly under commercial pressure, into a fixed and mechanical technology, with theories and procedures taken for granted.*

(2) *Although programed instruction has within it the potential to turn the attention of education and educational research more intensively and productively than ever before to the processes by which humans learn, there is very little sign that it is being used productively to test*

*theories of human learning or theories of cognitive process, or to enlighten the teacher concerning the process by which she teaches.**

(3) *Although programed instruction is essentially a revolutionary device, in that it has the potential to help free man from some of his bondage—the waste of human resources where there are no teachers or where people cannot go to school; the waste of time and talent where all students are locked into the same pace, and all teachers into the same routine; the tyranny of tradition which permits the study of a certain topic to begin only at a certain age, and expects a student to accomplish only so much as a questionable test of his ability says he can do; and the inadequacy of outmoded and inadequate curricula—despite this, programed instruction is very slow to rise to such a revolutionary potential.*

*As this was going to press, however, a new volume has appeared which represents a considerable contribution to theory. This is *Student Response in Programmed Instruction*, a collection of papers on research edited by Arthur A. Lumsdaine. The experiments it contains derive not from the influence of Skinner, but rather from the tradition of research on teaching films begun during World War II under Hovland, and since carried on under the general direction of scholars like Lumsdaine. Therefore, this volume represents the confluence of another current of research with the Skinner current, and both have come together on the same group of variables—cueing, fading, confirmation of results, size of step, overt vs. covert response. It is the most important book of research yet published on programed instruction, and fulfills some of the promises of contributing to a theory or science of instruction which, as indicated above, has been expected from experiments in programed instruction.

PROGRAMED INSTRUCTION TOMORROW

IF THIS SUMMARY of the present situation bears some relation to reality, then we are in position to make some projections into the future and suggest lines of healthy development toward the "revolutionary potential" of the method. It is not necessary to describe these in great detail. Here we shall merely set forth, so to speak, the skeleton of a desirable development, on which the scholars and builders of this field will know how to place the necessary flesh and blood.

(1) *More of the effort at making programs must be placed on the growing edge of the art, rather than the safe and conservative commercial "center."*

(2) *More research must be directed toward the larger implications and theoretical problems of programed instruction; in order to accomplish this, long-term commitment of top-level researchers will be required.*

(3) *The schools must make more imaginative applications of programed instruction, accompanied by developmental research and testing.*

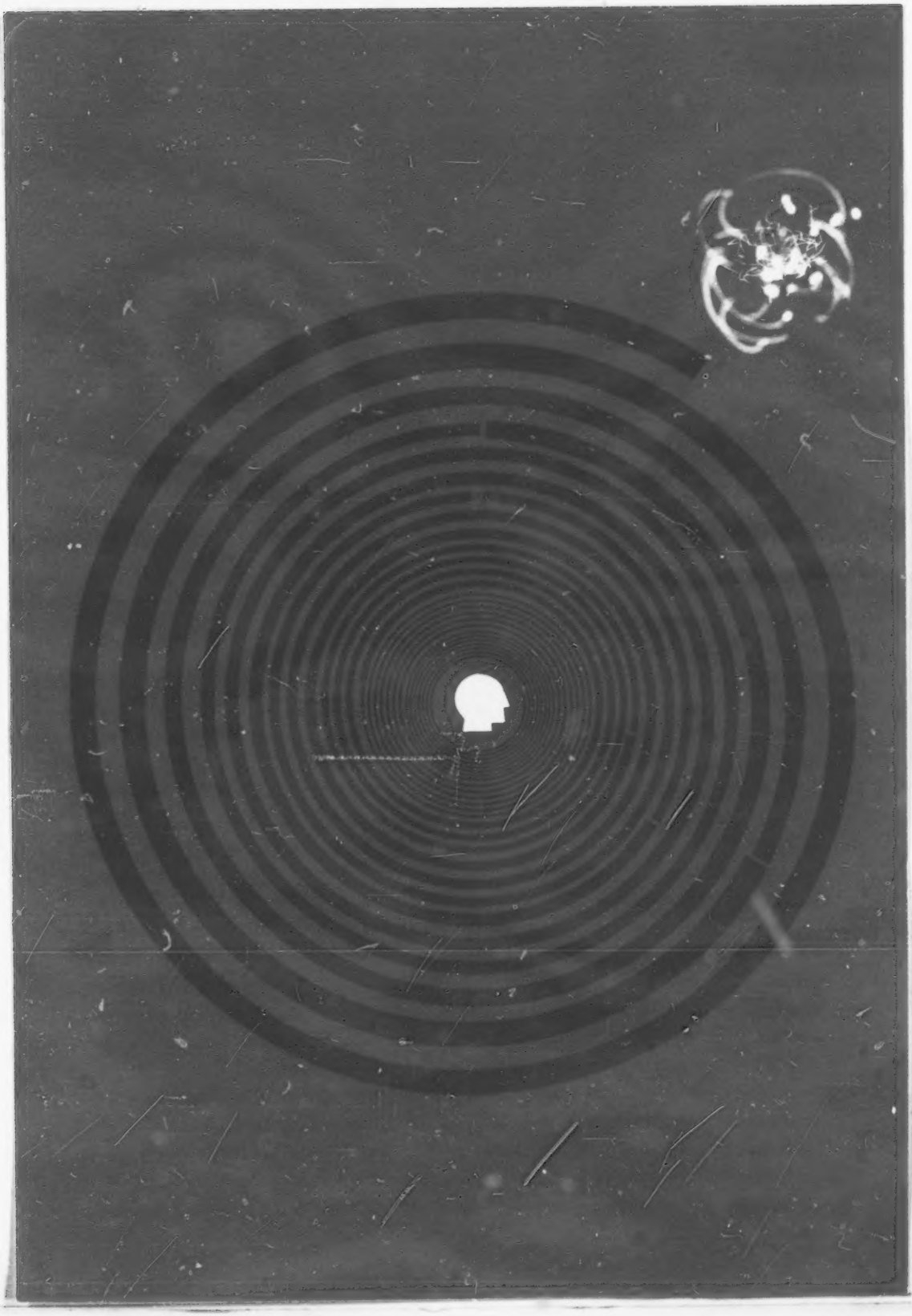
(4) *Teachers must be trained to use programed methods expertly; and the possibilities of making and using programs should be explored as one introduction to the human learning process in teacher training.*

(5) *Other channels of teaching—such as television, textbooks, films and other audio-visual means, workbooks, class teaching, and group study—must be examined to see where they can beneficially apply some of the principles of programed instruction.*

(6) *The skills and understandings of programed instruction must be shared with the developing nations, and used where possible to speed economic and social development.*

(7) *Adequate channels of information must be established among the many and diverse people interested in the development of programed instruction.*

This represents a very large program, but the stakes, too, are very large, and the goals most attractive.



A Few Suggestions for Further Reading

Readers who would like to learn more about programed instruction will find an interesting non-technical introduction to it in an article in the Scientific American *by one of the founders of the method—"Teaching Machines with Biographical Sketch," by B. Fred Skinner (Nov., 1961, pages 36, 90-102).*

An excellent scholarly introduction to the topic is Edward J. Green's volume, The Learning Process and Programmed Instruction *(Holt, Rinehart, and Winston, 1962). This brief book is not difficult reading for anyone with an elementary knowledge of psychology.*

Many of the early theoretical papers on programed instruction, including Skinner's famous article of 1954, and some discussions of the making of programs, are to be found in a large collection, Teaching Machines and Programmed Learning, *edited by Arthur A. Lumsdaine and Robert Glaser (published by the National Education Association, Division of Audio-Visual Instruction, Washington, D. C., 1960).*

Most readers who become interested in the method, however, will want to examine a program or programs. An introduction to most of the programs available for purchase in mid-1962 is a volume edited by P. Kenneth Komoski for the U. S. Office of Education, (and published by that Office, Washington, D. C., 1962). The book is entitled Programs '62. A Guide to Programed Instructional Materials *(OE 34015). It contains brief samples of most of the programs listed.*

The Office of Education has also published a brief account of teaching machines on the market in Teaching Machines and Programed Learning, A Survey of The Industry, 1962, *prepared by James D. Finn and Donald G. Perrin.*

Within a few months the Office of Education expects to make available an extensive bibliography of research on programed learning annotated by Wilbur Schramm.

A NOTE ON THE RESEARCH ABOUT PROGRAMED INSTRUCTION

Although perhaps no other teaching medium has ever owed its origin in such full measure to basic research, as opposed to art or technology or empiricism, still programed instruction is so new that the research on it is young and fragmentary.

There were only a few research papers on the method, based largely on the Pressey punchboard or on military trainers, before Skinner's theoretical article in 1954, and the research that followed took five years and the National Defense Education Act before it reached any considerable volume. Most of the papers here referred to were published in 1960, 1961, and 1962.

Because the field is so new, many of the research reports on programed instruction still appear in mimeographed or offset form, rather than in the journals. Therefore, it is very hard to know whether one is reviewing all the research or not. This review has undoubtedly missed some worthwhile papers, for which we are sorry. There is also a question as to what are the limits of the research on programed instruction. In one sense, all research on

learning and reinforcement is basic to programed instruction. In another sense the rich and useful articles on the art of programing which grow out of the experience of writing programs and testing them on a few individuals, are also part of the research on the method. However, nothing is listed here which is not an experiment, with the appropriate statistics applied. Commentaries, how-to-do-it articles, and theoretical articles (even Skinner's) which do not report research have been excluded.

The reader should be warned that some of these experiments have been done with very small experimental groups, and some of them with very short programs. How much of the result can be generalized to classroom practice can only be judged, therefore, by examining the individual study. We shall try to make this easier, at a later time, by adding rather full annotations on all the research studies.

As this was about to go to press, a volume appeared which illustrated the uncertain boundaries of the literature on programed instruction. This was *Student Response in Programmed Instruction,* edited by A. A. Lumsdaine, and containing a number of previously unpublished scholarly papers, some of which dated back to the early 1950's. In the narrow sense this book is not research upon programs—that is, programed texts, or taped programs in teaching machines. In almost every case it uses training *films* as stimuli. But most of the variables used in the experiments of the Lumsdaine book are precisely those used in the experiments on programed instruction more narrowly considered: size of step, nature of cue, spacing and amount of practice, confirmation of results, overt or covert response, and the like. Indeed, this book has a special importance in that it represents a confluence of another current of re-

search with the current stemming from Skinner. The Lumsdaine book stems from the army research in training films conducted during World War II under Hovland and others, and from the Hovland-Lumsdaine-Sheffield volume on *Experiments in Mass Communication,* published in 1949. Thus it really antedates the Skinner influence. The fact that these two currents should now converge on the problems of "programing" instruction and creating a science of instruction is very important for the future of teaching materials and method, and will undoubtedly open new paths and new insights, as well as contributing new talent, to research in the area. Therefore, we have had no hesitation in including papers from *Student Response in Programmed Instruction* among those here considered.

The following notes have been organized around two main questions, the second with several sub-questions: Do students learn from programed instruction? And what are the known conditions of its effectiveness—specifically, stimulus conditions, response conditions, and feedback conditions?

Do Students Learn From It?

Programed instruction has been tried, and has accomplished learning, at every level from preschool (for example, Alter, Eigen, and King, 1962; Glaser, Taber, et al, 1961) to graduate professional school (Ferster, 1960; Green, 1962). It has been used successfully with slow learners (for example, by Smith and Quackenbush, 1960, and by Stolurow, 1961), and on mature, superior students (Jensen, 1949). It has been used to contribute to the training of

pilots (Hatch, 1959), package and billing clerks (Hickley and Anwyll, 1961), electronics technicians (Benson and Kopstein, 1961), and computer operators (Hughes, 1961).

It has been used successfully to teach a great variety of subject matter—mathematics and statistics, foreign language, English language correctness, spelling, natural science, psychology, library use, and a number of industrial, business, and military skills. Examples of all these will be found in the literature.

It has been used successfully to teach a great variety of behaviors—among them, rote learning (e.g., Botkin and Goldstein, 1962), paired associate learning (Blyth et al, 1962), the application of formulas (Keislar, 1959), construction of deductive logical proofs (Evans, 1960), formation of concepts (Gagne and Brown, 1961), "thoughtful" reading (Reid, 1961), trouble shooting in electronic hookups (Cantor and Brown, 1956), reading a radar screen (Arnoult, 1956).

It has been used to teach all or part of the basic subject matter of a course (as in most of the examples below), or to supplement the main part of a course (as in Klaus and Lumsdaine, 1961, who tested the method as a supplement to Harvey White's physics lectures on "Continental Classroom"). It has been used in the classroom and at home. It has been used casually and without assignment or supervision; for example, when a teaching machine programed for some of the procedures of instrument flying was left in one squadron's lounge for a while, where it could be used or not used at will, that squadron progressed significantly farther in its instrument flying than other squadrons (Hatch, 1959).

It has been used successfully in the form of teaching machines, flash cards, programed texts—both horizontal and vertical—and

both visually and orally. It has been used effectively as programed films. It has been used successfully in many different styles—with or without branching, with different kinds of cues and prompts, with different amounts of repetition, with different size of step, overt and covert responses, constructed or selected responses, and with different kinds and amounts of reinforcement. Classroom lectures and television classes have been "programed," and increased learning has resulted (Roe, Massey, Welton, Leeds, 1960; Gropper and Lumsdaine, 1961).

The method has been used successfully in Great Britain as well as in the United States (for example, see Austwick, 1962), and apparently also in Japan, West Germany, and probably other countries, although research evidence for countries other than the U. S. and the U. K. has not come to our attention.

Although comparisons with "conventional" methods of teaching are difficult and sometimes suspect because there is always a lingering suspicion that apples are being compared with oranges, and because the "Hawthorne" effect of new methods and unusual attention may be at work, such comparisons as exist have shown programed instruction in a very respectable light. At Hamilton College classes in French, German, and logic were programed in part. For French, 35 visual units of 60 frames each, 35 corresponding audio units, and 35 units in a workbook were programed. Students taking this new introductory course averaged about 20 per cent higher on a standardized test of written French, grammar, and translation, than students in the former course. And although it may be argued that the average of college student ability has increased, still it is now possible to teach second and third year French courses at Hamilton entirely in French; this was not for-

merly possible. In German, three class periods a week plus three 20- or 30-minute laboratory periods with programed materials, have made possible an average gain of about 20 points on the standardized test over the averages made by students in the old course of five class periods and no laboratory. In logic, students worked through a program of 8,000 frames as a basis for class meetings; the class gained an average of 10 points, in the final examination, over the previous class which had not had the program.

Testing a spelling program in second and sixth grade classes, Porter (1959) found that in 22 weeks the group using the program learned significantly more than a comparable group taught by conventional methods. There was no significant relation between IQ and amount of learning in the experimental group, but there was the usual relationship in the control group. When 186 freshman engineering students at UCLA studied elementary probability by a variety of teaching methods—teaching machines of different kinds, programed textbooks of different kinds, "programed" lectures (i.e., lectures that followed the sequence of the programed items and encouraged student response), and conventional lectures, all the programed methods resulted in more learning than the conventional method (Roe, Massey, Welton, Gershon, and Leeds, 1960). Eleven Naval Reserve officers devoted 70 hours during 10 days to full-time study of the Russian language, working through a program, then moving to a study of grammar and of tape recording when they finished the program. The criterion was to become able to write simple Russian sentences and translate Russian passages into English. On the basis of tests, their instructor estimated that these officers learned about as much in

the 10 days as they would have learned in one and one-half semesters of a college course. An English study (Knight and Tilley, 1962) reported that Royal Air Force cadets, taught with a teaching machine, learned to a given criterion about twice as fast as a conventionally taught class.

Oakes (1960) reported no significant difference between sections of an introductory psychology course taught by programed instruction and by conventional methods. Twenty-four mature students (Jensen, 1949) completed a five-semester-hour college course in psychology in five weeks, using a Pressey punchboard program in an independent study laboratory, and 54 per cent of these students made A on the final examination, as compared to 10 per cent so graded in the other sections. (Of course, these mature and apparently motivated students might well have made A in conventional classes also.)

Pharmacy students in Pittsburgh were taught prescribed information about two vitamins by traditional lecture methods, and prescribed subject matter about two vitamins of comparable complexity by programed textbook. On immediate posttest, and again six weeks later, results were significantly in favor of the programed presentation (Glaser and Taber, 1961).

Instructors in the IBM company reported a class of computer programers completed their work in about half the time, using programed instruction, as was needed for conventional class methods (Hughes and McNamara, 1961). Benson and Kopstein (1961) reported no difference in the amount of learning of basic electronics from machine teaching and from conventional class teaching. Training for electronic trouble shooting by the traditional device of mockups was compared with the same training

using a program (Cantor and Brown, 1956); the traditional trainees proved superior in equipment usage, while the trainees who had used programs proved superior in understanding the troubles and their solution. Another study (Lowell, 1955) tried to train students to repair superheterodyne receivers by various combinations of oral instruction, practice on the actual receiver, and programed practice without the receiver. The programed practice made a significant contribution to the other activities, but proved to be an insufficient substitute for actual practice with the receiver.

Promising results have come from studies comparing programed with conventional teaching of slow learners. By use of a teaching machine, Smith and Quackenbush (1960) accomplished an average gain in arithmetic of .51 grade level, as measured by the California achievement test, in a group of retarded children (mean IQ, 77) whose corresponding average gain during the previous year had been .19 grade level. On the other hand, at least some programs appear to be relatively more effective for students of *high* ability (see Reed and Hayman, 1962).

The Sandia Corporation reports some cost figures on teaching by programed instruction. To teach Russian to their employees in conventional classes cost $57.15 per completion; to teach it by programed instruction cost $20.19. Algebra taught conventionally cost $20.50 per completion: the cost to teach it by program was $16.79. The cost of instructors' salaries was approximately the same for either way of teaching, but with programs the instructors could handle more students and got a higher percentage of completions (Teaching Materials, Inc., 1962).

Therefore, it seems reasonable at this time to lay aside the question of whether students *learn* from programed instruction.

They do. So far as we have evidence, they learn a great deal. The useful question is, rather, what are the conditions of effectiveness? From what kinds of programs, trying to teach what kinds of cognitions and behaviors, do students learn most? And for what kind of teaching, in what situations, with what students, are programs to be preferred to other methods of teaching?

From research, we know all too little about either of these questions—what makes for effective programs, and where programs are more effective than other methods—but we know much more about the first than about the second. Therefore, most of the remainder of this review will have to be concerned with the question of what makes for effective programs.

WHAT ARE THE CONDITIONS OF EFFECTIVENESS?

Styles of Presentation

In studies with fourth, eighth, ninth, tenth, and eleventh grade students, in three different locations, staff members of the Center for Programed Instruction, Inc., found no significant differences between amount of learning from a teaching machine and from a similar program presented in a mimeographed programed book, although it took longer to work through the program on the machine. Furthermore, there was no significant difference in the amount of learning when the same program was presented to one group as a vertically printed text (down the page) or a horizontally printed one (turning the page for each succeeding question). (Center for Programed Instruction, Inc., 1962; Eigen, Filep, Goldstein, and Angalet, 1962; Eigen and Komoski, 1960). Feldhusen and Birt (1962) found no difference in learning from the same program in a machine and in a printed folder. In general, this kind of finding is repeated through the literature.

Prompting, Cueing, and Confirmation

There are a number of articles in the literature about the relative merits of prompting and confirmation. In practical terms, one uses *prompting* when he studies foreign language vocabulary by putting both the English word and its foreign equivalent on the same side of the flash card, and *confirmation* when he puts one word on the front and the other on the back of the flash card. In prompting, one is supposed to learn the association by perceiving the terms in contiguity; in confirmation, one is supposed to learn by receiving the stimulus, making a response, and then quickly confirming or disconfirming it by looking at the correct response.

Three articles in which Cook was the major author (Cook and Kendler, 1956; Cook, 1958; and Cook and Spitzer, 1960) presented evidence that paired associates could be learned better by prompting. They also tested prompting and confirmation in each case with overt or covert response, and concluded that prompting without overt response was the most effective method in learning paired associates—because, they theorized, overt practice delayed the S-R reaction by interfering with the connecting of the stimulus to its proper response term. These results were supported by Kopstein and Roshal (1955) and Sidowski (1961), both of whom worked with the learning of foreign language vocabulary, by Shettel and Lindley (1961) working with the learning of the phonetic alphabet, and by Irion and Briggs (1957) who reported better results with prompting than with confirmation in accomplishing serial learning, paired-associate learning, and problem solving.

These results were puzzling to some psychologists, especially

to some to whom the response and its swift confirmation were very important parts of the learning process. Yet when scholars associated with Skinnerian programing experimented in the area, their results were not widely different from those just reported. For example, a doctoral dissertation by Hessert (reported in Glaser and Taber, 1961) tested (1) a "Skinner" program of short steps and continuous confirmation against (2) a "Cook" program of prompted paired associates against (3) a "Pressey" program of multiple-choice questions and no overt response, and found no significant differences in the learning which resulted from the several forms of the program.

Experimentation has moved toward the conclusions (a) that in many cases *partial* prompting is more effective than full prompting, (b) that the *nature* of the prompt is highly significant for transfer of learning to a testing situation, and (c) that *fading*, the gradual withdrawal of cues, may provide the most efficient situation for learning in many cases.

Thus, Angell and Lumsdaine (1960, 1961) found that the effectiveness of prompting is greater when the learner is asked to respond without prompting every fourth time. The method usually employed by Cook also was really a mixture of prompted and unprompted responses, inasmuch as every few times the learner was given an unprompted test trial. Angell and Lumsdaine concluded that prompting is clearly very powerful for many kinds of paired-associate learning, and that the optimum amount of prompting, and the gradient for withdrawal of prompts, depend on the nature of the task and the procedures.

One of the most important considerations, they decided, is for a program, of whatever kind, to make sure that the *correct* response

is given before the learner goes on to the next item. Another very important consideration is the relation of the cues given in prompting to the cues to be offered in the test situation. Pictorial in addition to verbal cues have been found very helpful when the task involves motor skills other than writing or speaking. Roshal (in Lumsdaine, ed., 1961) tested a number of film devices intended to present a task as realistically as possible, in relation to the way it would be seen when actually done without prompts. He found, for example, that a subjective camera angle—in which the camera was placed approximately at the position of the learner's own eyes when he did the task—resulted in more efficient transfer of learning and better performance on the task itself.

Different degrees of prompting appear to work better for different purposes and subjects. Stolurow (1961) tried both prompting and confirmation with retarded children, and found that when practice time was short, prompting worked better than confirmation; but that when there was a long practice period, confirmation resulted in more retention. Kimble and Wulff (in Lumsdaine, ed., 1961) found that one of the chief effects of additional prompting, or "response guidance," was to eliminate common errors, suggesting the usefulness of studying the errors students commonly make in a number of fields.

There are some interesting studies of fading. Glaser and Taber (1961) report on the teaching of color names to five- and six-year-olds by gradually withdrawing the color cues; in teaching blue, for example, there might be pictures in blue, decorations in blue, the word "blue" printed in blue ink, and so forth, and these cues are gradually withdrawn leaving the word "blue" (in black ink) mentally associated with the color. An ingenious study by Schafer

(also reported by Glaser and Taber) tried to teach German words by substituting them, more and more frequently, for their English synonyms in a passage of English fiction. The redundancy of the English language helps the reader absorb these new terms into the meaning. In the first sentence, for example, only the German word *die* may be substituted for *the*. By the end of the story, however, a large part of the text is in German. Whatever the linguists and teachers of foreign language may think of this method, it apparently succeeded in teaching students about two-thirds of the German words introduced into the story.

Several scholars have studied fading by visually reducing the strength of the cue. For example, Israel (1960) varied the clarity of the cue by printing it in different degrees of blurredness, and found that successively smaller amounts of prompting are required to attain correct responses, as the student works through the program. Guthrie and Lumsdaine (1961) taught the airport code letters corresponding to city names by prompting (studying a list of the pairs), confirmation (two-sided flash cards), and partial cueing (stimulus term introduced first, but immediately with it a dim printing of the desired response term, gradually fading out). They found a weak superiority of partial cueing over confirmation, but elicited so many excellent performances by prompted groups that they decided, for many occasions, "immediate full prompting may frequently represent an optimum condition, and . . . the various partial-cueing methods simply provided varying approximations to this immediate full-prompt situation."

Studies of optimum gradients have not often produced generalizable results beyond the statement of Lumsdaine that, at any given point in the program, the strength of prompt or cue should be just

sufficient to elicit the correct response and no stronger than required for this purpose. Briggs (in Lumsdaine, ed., 1961) compared three gradients without obtaining significant differences. MacDonald and Allen (1962) tried a variety of prompting and confirming methods, with no significant differences resulting. Della Piana (1962) found no significant difference in learning from several degrees of formal cues leading to confirmation, and from prompting. Campbell (1961), teaching 8th, 9th, and 10th grade children about static electricity by means of a Skinner-type program, tried to ascertain whether some subjects did better with rather full prompting, others with indirect cues. He got weak differences—of the order of two and three per cent.

McNeil and Keislar (1962) tried to find out whether first and third grade children would learn more from a program written in question, rather than in statement, form. The hypothesis was that covert responding would occur more readily to question. They found no significant differences.

Gagne and Brown (1961) constructed three versions of a program for teaching 9th and 10th grade children to devise formulas for the sum of terms in unfamiliar number systems. The three versions were a "ruleg" type program in which each of the concepts was stated and then illustrated, a "discovery" program in which the student was given materials from which he could actively produce the desired concepts, and a "guided discovery" program in which the student was guided through the material toward the desired discovery. All three programs produced significant learning, but the guided discovery program was productive of the most learning, the discovery program next, and the more orthodox program least. The finding that concept discovery

can effectively be engineered by a program is very important, in view of the importance of discovery in the new science and mathematics curricula.

Sequence of Items

Many programers and observers of programing believe that one of the chief reasons why programed instruction is effective is that the ideas in a program are presented in a logical and strategic way. Considering that very wide belief, some of the studies on sequence of items are, to say the least, puzzling. Two of four studies of logically sequenced programs vs. the same program with items in a random order (Roe, 1961; Gavurin and Donahue, 1961; Zuckerman, Marshall, and Groesberg, 1961; and Roe, 1962) found no significant difference in the learning from the two kinds of program; the other two did find a difference. For example, when Gavurin and Donahue tried 29 psychology items, in random and in logical sequence, on 40 subjects, they found fewer errors during trial and fewer trials to criterion on the part of those who studied the logical sequence. But even in this case, there was no significant difference between the two groups on a delayed post-test. It should be pointed out that some of the effective unsequenced programs have been very short and perhaps of such a nature that logical sequencing would not greatly help students to learn from them.

Mager (1961) tried the interesting gambit of allowing six adult students to learn a given content themselves by asking questions of an instructor. These patterns bore little resemblance to conven-

tionally written logical sequences. The investigator noted, however, that the students seemed to gain motivation from the fact that they were controlling the process—suggesting one reason why some tightly controlled linear programs are considered dull.

Size of Step

The cognitive leap from step to step is an important problem for all programers, and Skinnerians tend to say that the step should be very short so as to keep error at a minimum. Evans, Glaser, and Homme (1960) found some research evidence for this in a study which used different versions of a program intended to teach a method of conversion to unfamiliar number bases. The different versions covered the same material but had respectively 30, 40, 51, and 68 steps. The groups who had the smaller step programs (51 and 68) made fewer errors during the program and performed significantly better on the posttest. The group with 51 steps did slightly better than the group with 68, suggesting that there may be an optimum size of step somewhere between too long and too short.

On the other hand, Smith and Moore (1961) found no difference in rates of learning to spell related to variation in size of step. This may be because spelling is pretty much rote learning anyway, and perhaps does not depend so much on sequence as does concept or tool learning.

Studying fourth grade children, Shay (1961) found no relation between intelligence and step size in determining maximum learning from a program.

Maccoby and Sheffield (1958; and in Lumsdaine, ed., 1961) taught an assembly task from filmed demonstration. The chief variation that affected performance was the length of filmed sequence demonstrated before each practice period. This, of course, corresponds to size of step. Short steps worked better than long ones. The best result of all was obtained by starting with short steps, then gradually lengthening them out. Worst results of all came from demonstrating the whole sequence before practice—the longest possible step.

Branching

If there is a different optimum size of step for different students, then the solution might seem to lie in branching—introducing remedial or explanatory loops, or review passages, into a program for learners who need them, while permitting swifter learners to skip the extra practice. This is one of the advantages claimed for Crowder programing, where it can be handled more easily than in Skinnerian programs.

A chief source of research information on branching in Skinnerian programs is a series of eight experiments reported by Campbell (1962) from the San Mateo office of the American Institute for Research. Campbell used two programs, one on sets and numbers, the other on the United Nations, and tested each one in a "bypass" (branching) form, and in linear forms of different length. In most cases he had a short form of each program (with fairly long steps), a "bypass" form in which the short program was supplemented by remedial and practice loops for users who needed

them, and a long form in which the additional practice was built into the program, thus reducing the size of step.

He got significant differences in learning more often with the UN program than with the mathematics program, although throughout he found considerable time differences proportional to the length of program. Where he got significant differences in learning they tended to be of this nature: in the high school, an advantage for the branching program over others, especially among the higher ability students, who were thus permitted to skip repetitions and work at optimum speed; in the elementary grades, more often an advantage for the longer program and the branching program over the shorter one, suggesting that where material is relatively more difficult, more practice is useful. Roe (1962) found no significant difference between learning from a linear and a branching program, but found forward branching more effective than backward branching. The net conclusion is that effective branching can be introduced into a Skinnerian program, but where and how it can be most effective are questions not yet fully understood.

Review

The amount of review introduced into the program is another factor somewhat related to size of step and to the problem of branching. Holland and Porter (1960), using a machine with the ability to drop out and repeat a missed item, found that a group which did receive the repeated items made significantly fewer errors on both an immediate and a delayed criterion test. Six

months later, for some reason, the group which had this repetition required significantly more training time than the group which did not have it.

Rothkopf (1961), using only eight paired-associate items, found no significant difference between groups which had a missed item repeated until they had made *one* correct response, and those for whom it was repeated until they made *two* correct responses.

Ferster (1960) tried repeating entire lessons. Using the first 61 lessons of the Holland-Skinner program, he found no significant gain in repeating whole lessons, and concluded that the more significant kind of review was that already built into the lessons.

Pacing

There seems to be little doubt that students like to pace their own learning. Where effectiveness of a student's self-pacing vs. machine or instructor pacing has been measured, and differences have been found, they have usually been in favor of self-pacing. Follettie (1961) found self-pacing to be superior to forced pacing on an efficiency measure incorporating test score, training time, and testing time. Maccoby and Sheffield (1958) found that for superior students, a self-pacing procedure worked best. Moore and Smith (1961), Briggs, Plashinski, and Jones (1955), and Silverman and Alter (1961), however, found no significant differences when the student controlled the pace or it was controlled for him. These latter findings may help to explain why programed lessons on television are more effective than we might expect them to be,

considering that all viewers have to fit their pace to that of the telecast.

Response Conditions

The overt, constructed response has traditionally been an important element in Skinnerian programing, and the multiple-choice, selected response an important element in Crowder programing. A third response variation—covert responding—has come in for frequent discussion and testing, and so also has the device of having the subject read the items with no words omitted.

Overt vs. Covert Responses

A well-known experiment reported in Hovland, Lumsdaine, and Sheffield's *Experiments on Mass Communication* (1949) indicated that active response might be an important element in learning from verbal material. In this experiment, viewers of a film designed to teach the military phonetic alphabet (A, Able, B, Baker, and so forth) were found to learn more quickly if they called out the correct equivalent of the letter when it was shown on the screen. A follow-up on this experiment by Michael and Maccoby (1953) found covert or subvocal response was almost as effective as overt written response, but analyzed the source of gain from active responding as primarily due to specific practice effects. Kanner and Sulzer (in Lumsdaine, ed., 1961) found no significant advantage of oral recitation, written practice, "thinking the

answers," or "thinking plus feedback," over any of the others in contributing to learning from a teaching film. A study by Gropper and Lumsdaine (1961) comparing a conventional televised lesson with one that was "programed" to encourage active response by the audience, reported presumptive evidence of the effectiveness of such active responding, but only if *correct* responses were made. With the low ability group, this proved to be an especial problem. If these subjects were permitted to respond incorrectly all the beneficial effects of active response were lost.

Results favoring the use of overt response have not often been found when actual programs were studied. Here a frequent finding has been that subjects gain about as much from covert responses and take significantly less time working through the program. Two studies actually found more learning from covert responses under certain conditions (Silverman, 1961; and McGuire, in Lumsdaine, ed., 1961). A number of studies report no significant differences between the two response modes. Among these are Keislar and McNeil (1955), Evans, Glaser, and Homme (1960), Goldbeck, Campbell, and Lewellyn (1960), Kormondy (1960), Silverman and Alter (1961), Stolurow and Walker (1962), and Lambert, Miller, and Wiley (1962). Taking into account the non-significant difference in learning but the significantly less time required to do the program, some studies have concluded that covert responding is more "efficient" than overt: among them, Silverman and Alter (1961), Evans (1960), Silberman, Melaragno, and Coulson (1961), Sidowski (1961), Hughes (1961), and Center for Programed Instruction, Inc. (1962).

On the other, Goldbeck (1960), using items at different levels of difficulty, found overt responses made for more learning of

more difficult items, but were less effective with easier items. Krumbholtz and Weisman (1961) found no significant difference on an immediate posttest of learning from overt and covert responses, but that the overt group did better on a two-week-delayed retention test. It is a fair assumption that there may be some interactions between overtness of response, difficulty of program, and ability of learner, which have not yet been fully explored.

An experiment by Csanyi (reported by Glaser and Taber, 1961) studied different modes of overt responding. He divided 30 junior high school students into three groups who were taught the pronunciation of Spanish words by means of three different kinds of practice: saying the words as suggested by printed English syllables of approximately the same sound, imitating the pronunciation of native speakers from a tape recording, and using both the English equivalents and the tape recording. At the end of the practice period the student recorded his pronunciation of these words, and the results were judged by Spanish teachers and native speakers. No significant differences were found.

Constructed vs. Selected Responses

Using flash cards to train students to a given criterion of correct response to meaning of Spanish words and phrases, Fry (1960) found the constructed response group superior on a short constructed-response test, although they had taken significantly more time to reach the criterion in training. Coulson and Silberman (1960) also found that multiple-choice programs required signif-

icantly less time, but found no significant differences in the amount of learning resulting from the two forms. Hough (1962) found no significant differences related to constructed or selected responses, or a combination of them. Zuckerman, Marshall, and Groesberg (1961) found no significant differences in the learning from constructed responses, multiple-choice responses, or true-false responses. Burton and Goldbeck (1962) found no over-all advantage of one form over the other, but did find an interaction between response mode, student ability, and presence or absence of the desired response in the student's previous repertory. Arnoult (1956) found that training of bombardiers to recognize complex visual patterns was more effective when they responded by drawing patterns than when they responded by describing them verbally.

It is reasonable, therefore, to suppose that in the case of constructed vs. multiple-choice responses, as in that of overt vs. covert responses, there are more elements involved than the two major ones, and the interaction is far more complex than a twofold one. Some of the elements may well be student ability, difficulty of the responses, the kind of learning that is being sought (recognition or recall, conceptual or factual, verbal or pictorial, and so forth), the nature of the criterion test (multiple-choice or constructed response), and the amount of practice built into the test.

Reading vs. Responding

The research on paired associates should prepare us for the fact that often a great deal of learning results from merely reading programed items with the blanks previously filled in. (This will not

surprise textbook publishers.) Krumbholtz and Weisman (1961), for example, compared a group (1) who wrote down each response in a program, with another group (2) who mentally composed the response but did not write it, with a group (3) who read the programs with the blanks already filled in, with a control group (4) who read another program entirely. They found a significant amount of learning in each of the experimental groups, and no significant difference between them on an immediate posttest, although two weeks later group number (1) retained more of what they had learned. Campbell used another variation of this design, comparing a group (1) who wrote in the response only when sure of its correctness, with a group (2) who wrote answers in every blank, whether sure or not, with group (3) who did not write the answer but mentally composed it, with group (4) who read the same program with no words omitted—no blanks to fill. He, too, found no significant difference on an immediate posttest, but found a significant superiority for group number (4), the reading group, after ten weeks.

Holland (1960), on the other hand, compared a superior program requiring the student to notice the critical material the program was designed to teach, and to respond actively—compared this program (1), with a program (2) in which the items were ambiguous and difficult to respond to, with a program (3) in which all the blanks were filled in. He found more learning resulted from (1) than from (3), and more from (3) than from (2). Kaess and Zeaman (1960) reported some evidence more favorable to reading. Using a simulated Pressey punchboard, they found that reading the correct answers was as effective as *reading plus punching*.

It is clear that variables other than reading vs. responding are involved in determining when one of these works better than the other.

Feedback Conditions

Immediate vs. Delayed Feedback

Immediate knowledge of results is another major tenet of Skinnerian programing. This is one aspect of all the Skinnerian programs tested in the research literature, and therefore deserves part of the credit for their success. When the device is tested separately, however, the results are not quite unanimous. Michael and Maccoby, and Kanner and Sulzer (both in Lumsdaine, ed., 1961) found substantial evidence for the importance of giving the learner knowledge of his results. Angell (1949) compared students who were given immediate knowledge of their scores on a Troyer and Angell punchboard program, with other students who were given results only at the next meeting of the class. Final examination scores were significantly higher for the immediately reinforced group. Similarly, Meyer (1960) found significantly greater learning occurred in students who were given immediate confirmation of results than in students who received the same knowledge later when the teacher had corrected the answer sheets. On the other hand, Evans (1960) found no difference in learning resulting from immediate or slightly delayed feedback. Moore and Smith (1961) found no difference in the amount learned by sixth graders whether or not they received knowledge of results. And

Feldhusen and Birt found no difference in the amount learned from a program with or without knowledge of results, or with delayed knowledge of results.

Mode of Feedback

Scharf, in an M.A. thesis reported by Glaser and Taber (1961), experimented with different schedules of reinforcement in a Skinnerian program written for high school students. One hundred per cent continuous reinforcement was compared with 50 per cent fixed ratio reinforcement, with 50 per cent variable ratio reinforcement, and with 25 per cent variable ratio reinforcement. (Flash cards were used for the program, and it was possible to vary the schedule of reinforcement by omitting some of the confirmations from the backs of the cards.) On a multiple-choice criterion test, no learning difference could be found attributable to any schedule of reinforcement. It was suggested that reinforcement by confirmation may be a crucial event only when the probability of correct response is low; and in Skinnerian programs the probability is deliberately kept high.

Melaragno (1960) experimented with negative reinforcement, and found that the learning of a set of logic symbols was not much depressed by spaced negative reinforcement, but was significantly depressed by *massed* negative reinforcement.

Bryan and Rigney (1956) compared a group of college students who were given immediate knowledge of results, with another group who were given this information *plus* an explanation of why the choice was right or wrong, and both of these with

a third group who merely answered the items without knowledge of results. The items were multiple choice, and the test, one week after the exercise, was also multiple choice. The group who received *both* knowledge of results and explanation scored significantly higher.

When Bryan, Rigney, and Van Horne (1957) tried to pursue this finding farther, so as to find out *what type* of explanatory material might be most effective as a part of confirmation, they found no difference between the learning that resulted from explanations consisting of (1) correct definition or description of chosen alternatives, (2) the principal reason why the chosen alternative was keyed as correct or incorrect, or (3) probable operational consequences of the course of action represented by the chosen alternative. Krumbholtz and Bonawitz (1962) found that when they put the confirmatory term into a complete sentence, this "context" aided students to apply the learning to new problems.

CONCLUSION

Looking back over this brief and incomplete review of research, we are impressed by the observation that the studies in this area have so far contributed more to establishing the principle than the practice of programed instruction. The usefulness of active response to learning stimuli, of offering those stimuli in a sequence based on a tested learning plan, and of controlling the responses and feedback in a pattern designed to accomplish maximum transfer of learning to an unprompted task—these are now supported by several years of practice with programs, by roughly 100 experiments on programs, and by the impressive evidence on programed instruction in films provided by the 1961 Lumsdaine book. But the research evidence on how these concepts are to be applied to teaching materials is not very specific. For example, where can programs, in the narrow sense, be used to advantage over other ways of teaching? There is evidently an area where paired associates can be taught better by prompting. There is another area, apparently, where it works better merely to read the

statements from which the key information is to be learned. There is still another area where teaching by "discovery" is apparently the most effective way to the desired learning. Somewhere in the middle of these is an area where active-response programs probably do the best job. What are the bounds and limits of this area? To what extent can programed instruction teach by discovery, as the Gagne and Brown article seems to indicate it can do? And what are the most potent combinations of programed instruction with other teaching, to accomplish given educational goals?

One cannot help but notice the incompleteness of the research on the effective forms of programed instruction. The many non-significant differences may mean merely that students learn from almost any kind of program, as some programers say. On the other hand, they more likely mean that the full complexity of what is going on between the student and the program is not being studied. It certainly seems to be true that more elements than gross program styles and response modes must be fed into the design before we understand the interaction. As we have suggested, the ability of the student relative to the program, the kind of learning being sought, the kinds of response being elicited, the schedule and nature of reinforcement, the subject matter of the program, the previous learning experience of the student with the subject matter and with programs—all these and many others may very well enter into the understanding of what happens when a program of a given kind meets a student of a given kind. It must be admitted that, as of now, the reported literature really gives all too little guide to programers who would do a superior job. There is good guidance in the half dozen excellent articles on program making and in the example of successful programs. But for the most part

the research on which a programer must chiefly rely is not what we have here reported, but rather his own empirical study of the way his first test subjects respond to his program; those five, or six, or ten test cases, he may find more helpful than the same number of formal articles.

At present the research contains only a beginning of what it may eventually have to say about the application of programing methods to other teaching media. There have been a number of studies of programed responses to teaching films, and a few studies of "programed" educational television. The trials of programs to be read with the blanks filled in suggest a possible application to textbooks. There is one study of "programed" lectures.

While we are lamenting the lack of some types of study we must not fail to call attention to one aspect of the situation which is most hopeful. In the scholarly literature at the moment there is every hope that ways can be found to write programs vastly more effective and useful than present programs. The indication that discovery can be experienced through studying a program is a most important one. The indication that branching is feasible and effective in Skinnerian programs is likewise most promising. The suggestion in a few of the studies that the same program may be effective in different grades and at different ages holds out the hope that programs may become very useful in the ungraded school and in supplementing the work of gifted students. Conversely, the several evidences that programed instruction may be uncommonly effective for slow learners holds out the hope of a very special and needed service. When we understand more than we do now about how to combine different kinds of programing, how to vary the schedule of reinforcement, and how to fit a program to different

learning objectives and student abilities, above all when we learn more about how to maintain the student's interest and challenge him through what is now very often a very dull exercise in conditioning, then programs are likely to look far different from the way they look today.

ABOUT THE AUTHOR

Wilbur Schramm, Director of the Institute for Communications Research at Stanford University, has served as a consultant to various branches of the government, and has had a deep and continuing concern with communications and education. His latest book, TELEVISION IN THE LIVES OF OUR CHILDREN, was published in 1961 by Stanford University Press.

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